SCOSTEP
Scientific Committee on Solar-Terrestrial Physics

Variability of the Sun and Its Terrestrial Impact (VarSITI)

New SCOSTEP Scientific Program for 2014-2018

Nat Gopalswamy – SCOSTEP president

Katya Georgieva and **Kazuo Shiokawa** – VARSITI co-chairs

SCOSTEP
Scientific Committee on Solar-Terrestrial Physics

= Scientific Committee On Solar-TErrestrial Physics

Scientific Committee of ICSU (International Council of Scientific Unions) - non-governmental organization founded in 1931 to promote international scientific activity in the different branches of science and its application for the benefit of humanity.

SCOSTEP brief history:

- **Originally established 1966 as Inter-Union Commission of ICSU on Solar-Terrestrial Physics**

- **Reorganized in 1972 as a Special Committee of ICSU with responsibility for interdisciplinary solar-terrestrial physics programs** of finite duration.

- In **1978** became a **Scientific Committee of ICSU charged with the long-term responsibility to promote international interdisciplinary programs in solar-terrestrial physics**.

SCOSTEP

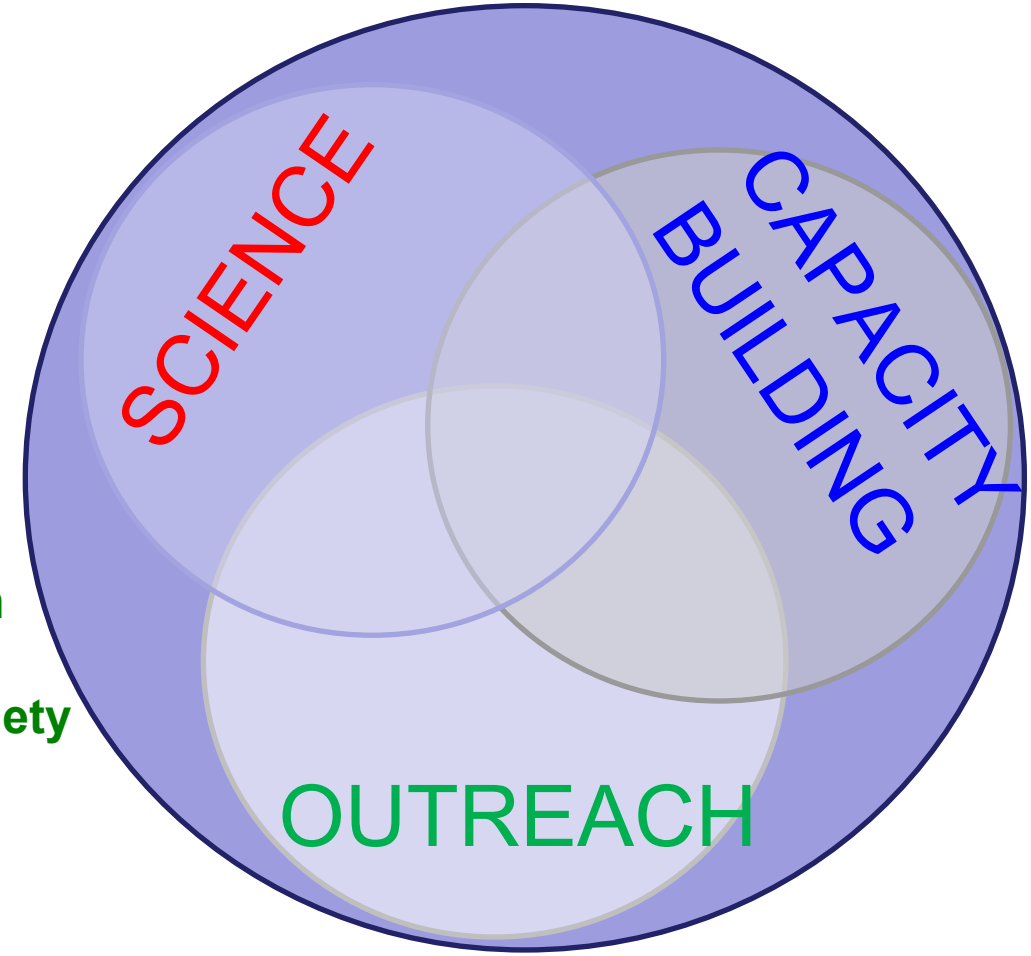
Scientific Committee on Solar-Terrestrial Physics

Interacts with national and international programs involving solar terrestrial physics elements to:

- run long-term (4-5 years) international interdisciplinary scientific programs In solar-terrestrial physics

- engage in capacity building activities

- disseminate new knowledge on the Sun-Earth System and how the Sun affects life and society as outreach activities



SCOSTEP
Scientific Committee on Solar-Terrestrial Physics

Completed international interdisciplinary programs in solar-terrestrial physics

- **1976-1979** IMS: International Magnetospheric Study
- **1979-1981** SMY: Solar Maximum Year
- **1982-1985** MAP: Middle Atmosphere Program
- **1990-1997 STEP: Solar-Terrestrial Energy Program**
- **1998-2002 SRAMP: STEP-Results, Applications and Modeling Phase**
- **1998-2002** PSMOS: Planetary Scale Mesopause Observing System
- **1998-2002** EPIC: Equatorial Processes Including Coupling
- **1998-2002** ISCS: International Solar Cycle Study
- **2004-2008 CAWSES: Climate and Weather of the Sun-Earth System**
- **2009-2013 CAWSES-II: Climate and Weather of the Sun-Earth System-II**

CAWSES 2004-2008: 4 scientific themes

- **Theme 1: Solar Influence on Climate**

  Co-Chairs: Michael Lockwood and Lesley Gray

- **Theme 2: Space Weather: Science and Applications**

  Co-Chairs: Janet Kosyra and Kazunari Shibata

- **Theme 3: Atmospheric Coupling Processes**

  Co-Chairs: Franz-Josef Lübken and Joan Alexander

- **Theme 4: Space Climatology**

  Co-Chairs: Claus Frölich and Jan Sojka

- **Capacity Building and Outreach**

  overall guidance of Prof. Y. Kamide

CAWSES II 2009-2013: 4 Task Groups

- Task 1. **Solar influences on Earth's climate**

  Co-chairs: Annika Seppälä, Katja Matthes, Cora Randall

- Task 2. **Geospace response to altered climate**

  Co-chairs: Jan Lastovicka, Dan Marsh, Gufran Beig

- Task 3. **Short-term solar variability and geospace**

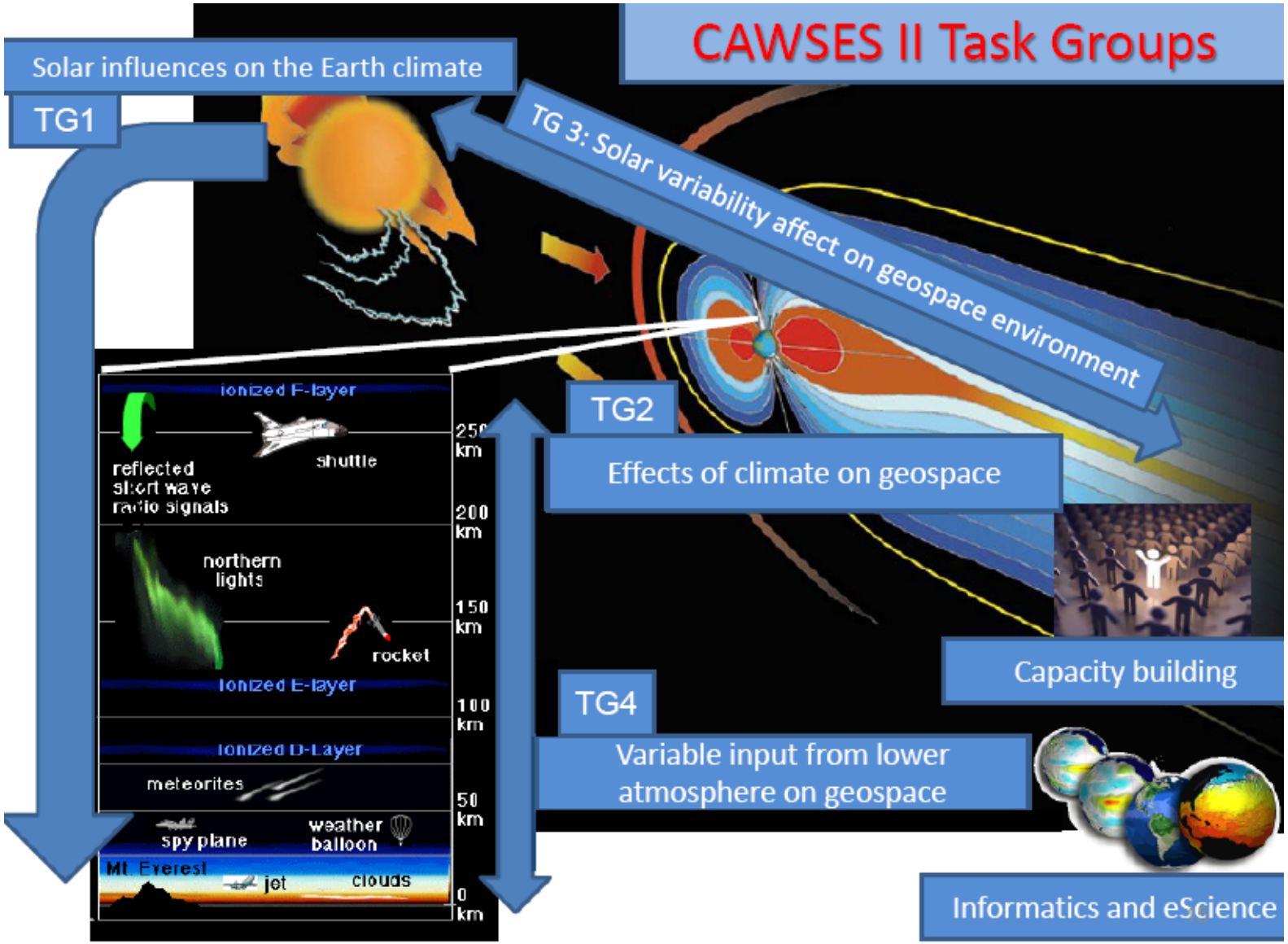
  Co-chairs: Kazunari Shibata, Joe Borovsky, Yihua Yan

- Task 4. **Geospace response to lower atmospheric waves**

  Co-chairs: Jens Oberheide, Kazuo Shiokawa, S. Gurubaran

- **Capacity building and outreach** – **Nat Gopalswamy**
- **e-science and informatics** – **Peter Fox**

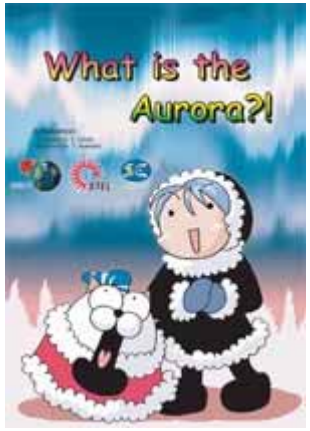
The task groups are inter-related

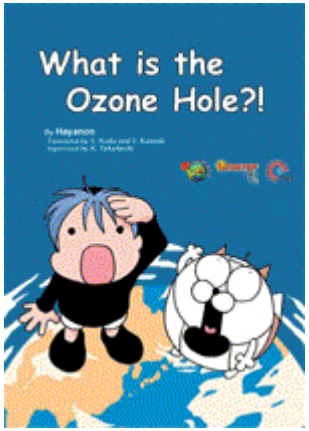


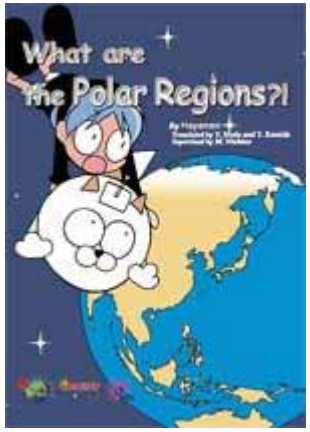
Capacity Building: Space Science Schools

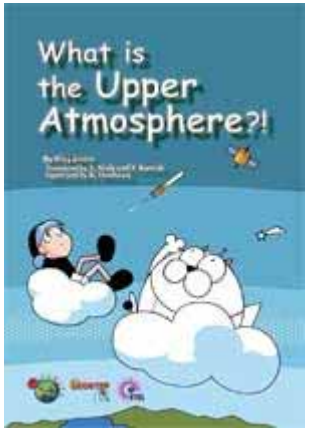
Indonesia (Sep 2012); Kenya (October 2013), Peru (2014)

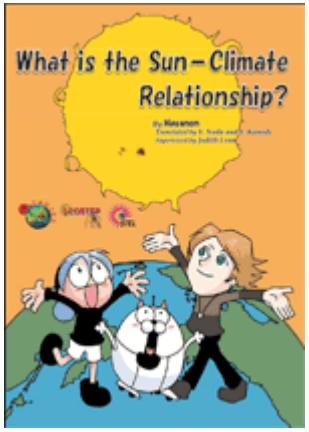
Partnered with International Space Weather Initiative (ISWI)

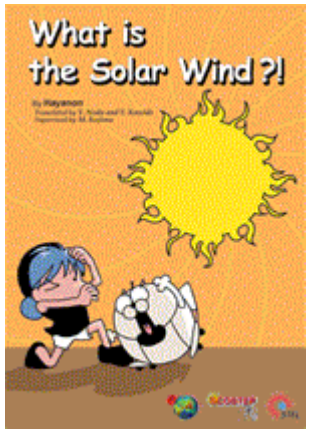


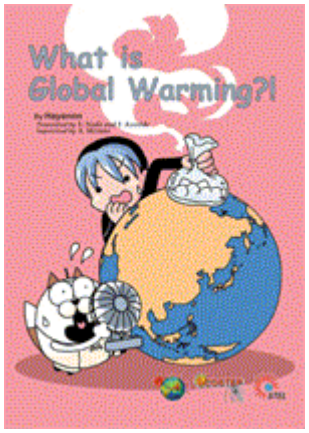


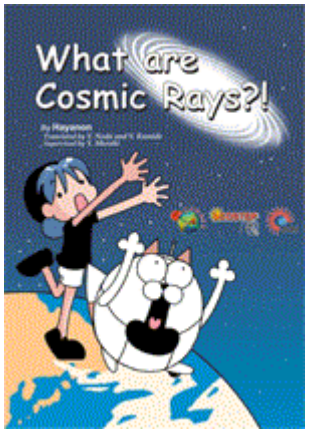










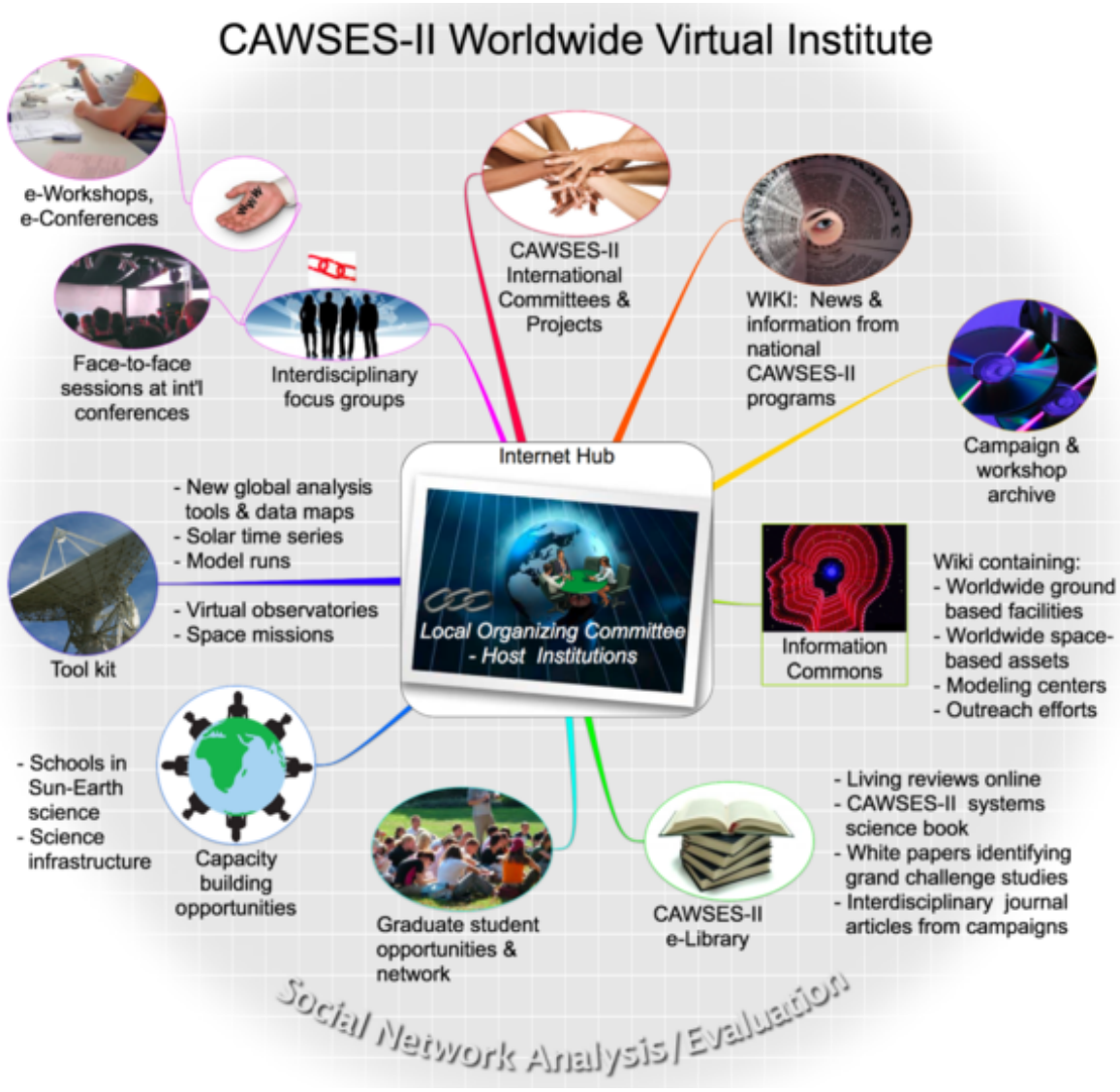


Outreach:
Comic Books

- To raise the awareness of general public, and young people in particular, on selected solar-terrestrial topics (currently 9)
- Initiative of prof. Yosuke Kamide, Solar-Terrestrial Energy Laboratory, Nagoya University
- Translated into 8 languages so far, ongoing translations into 9 more
- Available online: yorku.ca/scostep
- Translate into your language!

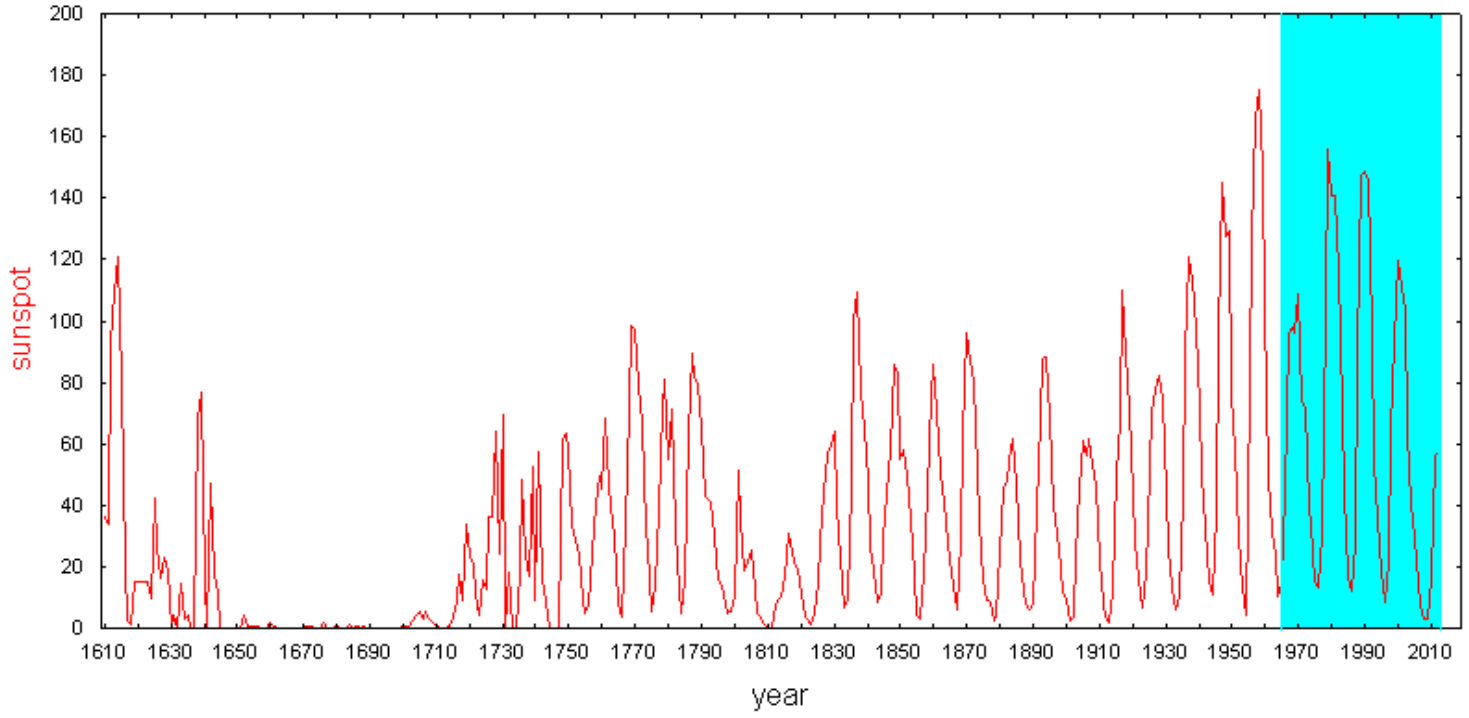
e-science and informatics

http://www.cawses.org/wiki/index.php/Virtual_Institute



CAWSES II ends in 2013

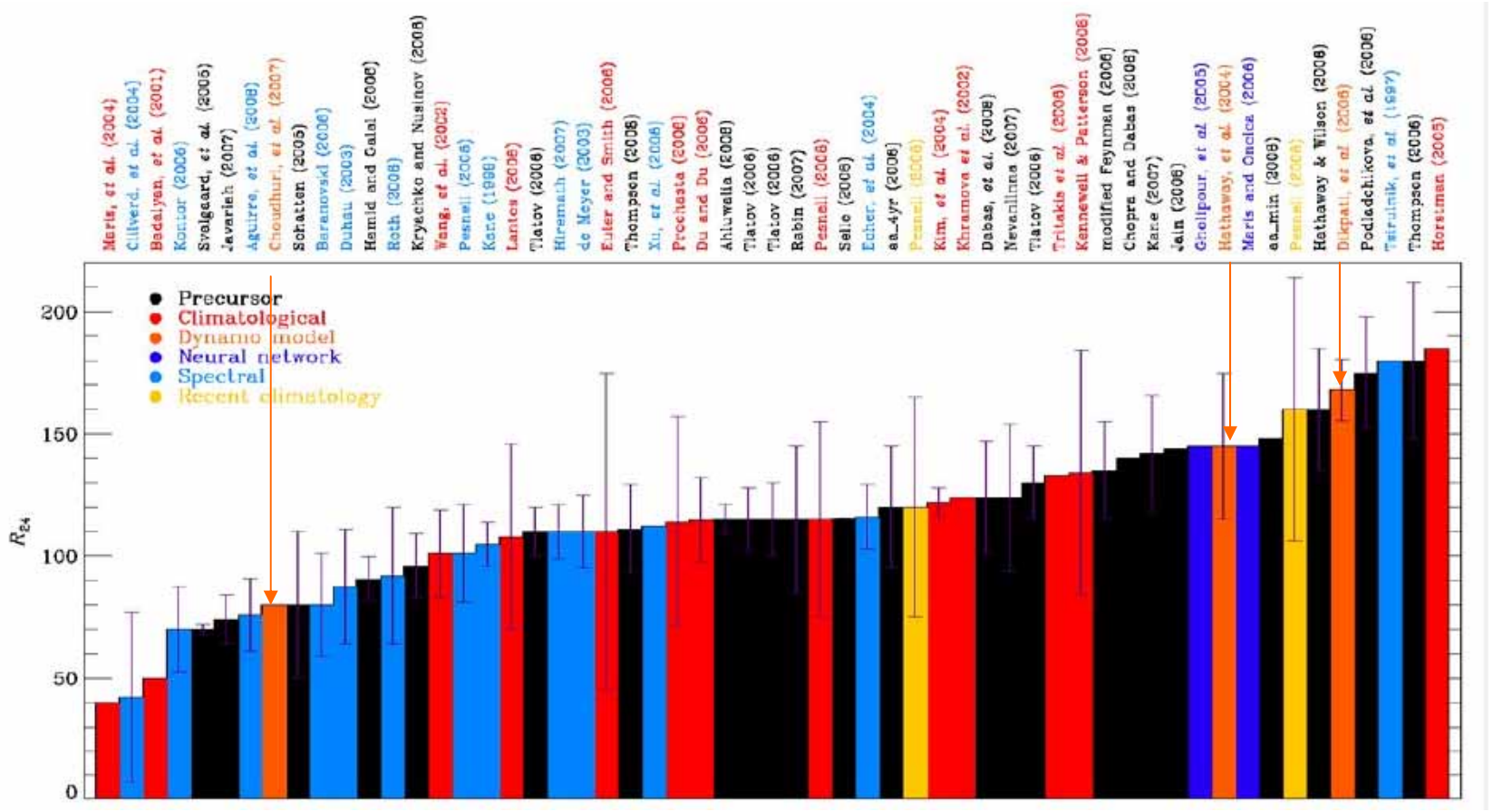
In the meantime: unusually deep and long sunspot min, low sunspot max



Challenges our understanding of the Sun and solar-terrestrial influences

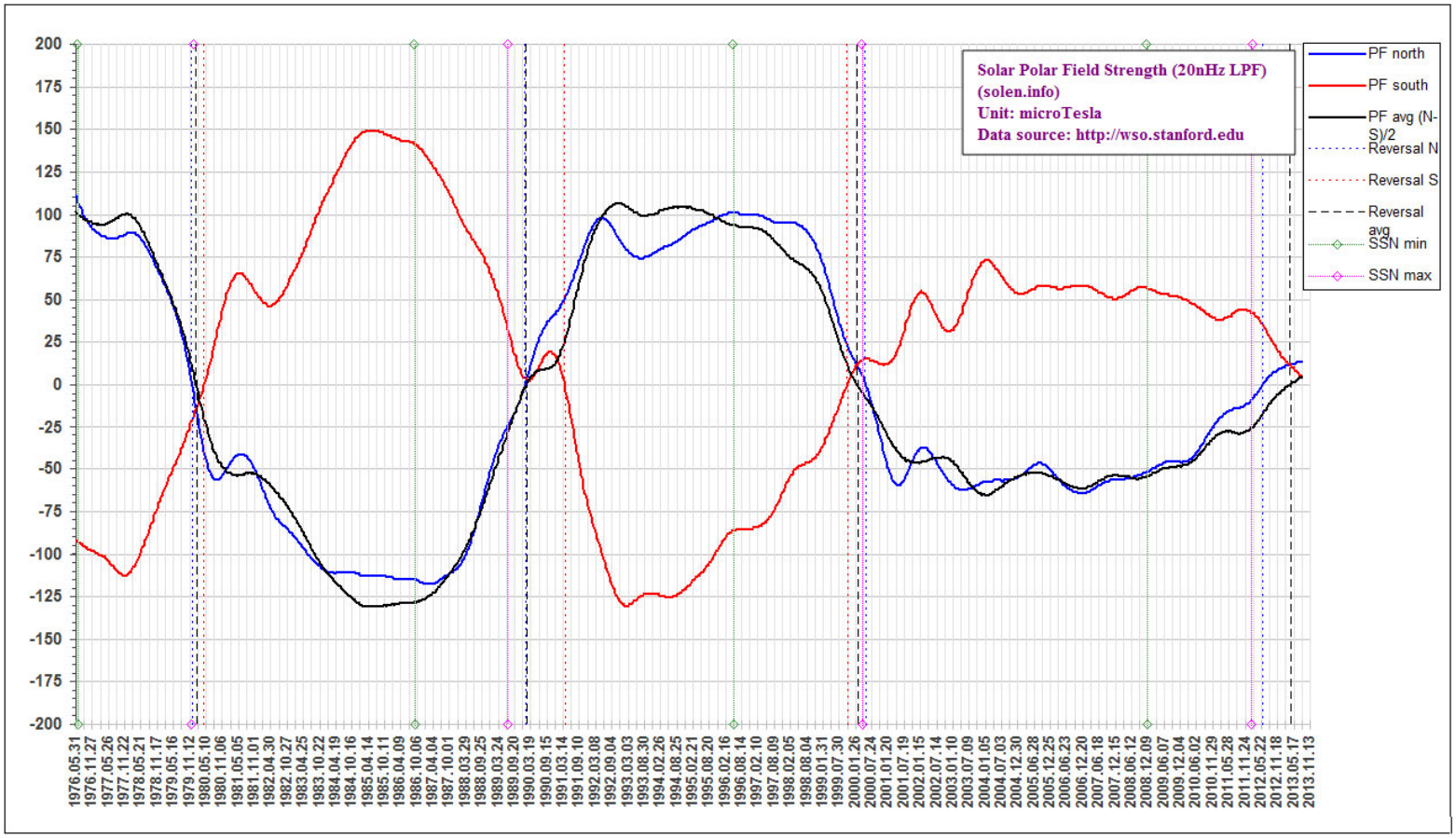
Most of the observations during the "space era" and the resulting theory are made during the recent modern grand maximum of solar activity.

How well can we predict Sun's activity?



Predictions of sunspot cycle 24

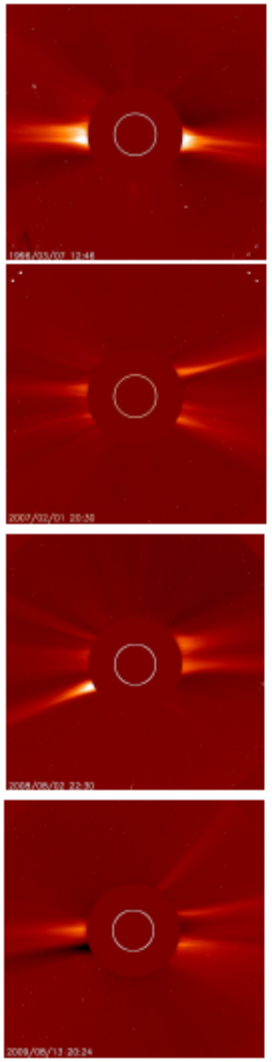
How well do we understand how the Sun works?



solar polar magnetic field record low

How well do we understand how the Sun works?

coronal morphology



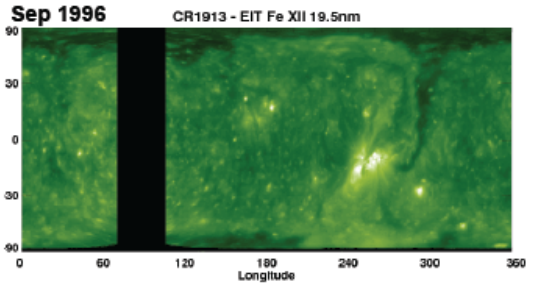
1996 ssn = 9.2

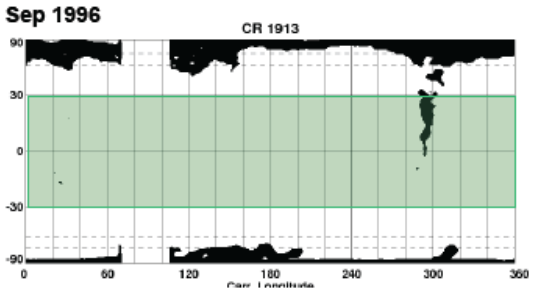
2007 ssn = 10.7

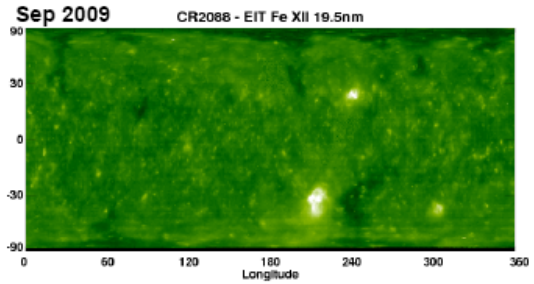
2008 ssn = 0

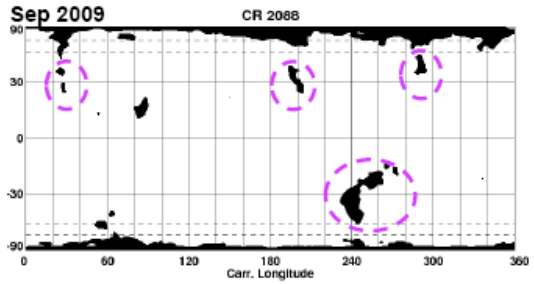
2009 ssn = 0

coronal holes



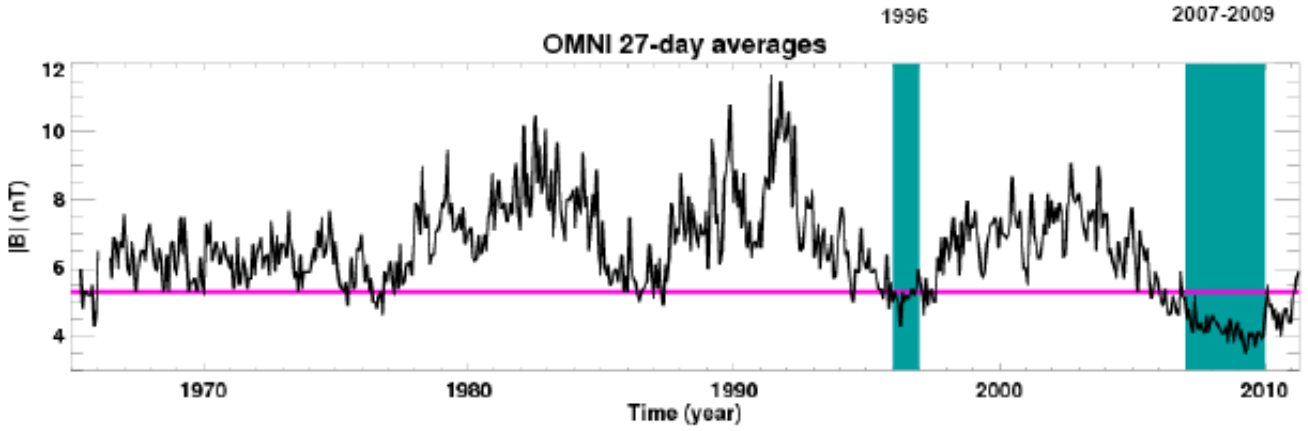






How well do we understand the relation between the way Sun works and its output?

INTERPLANETARY MAGNETIC FIELD

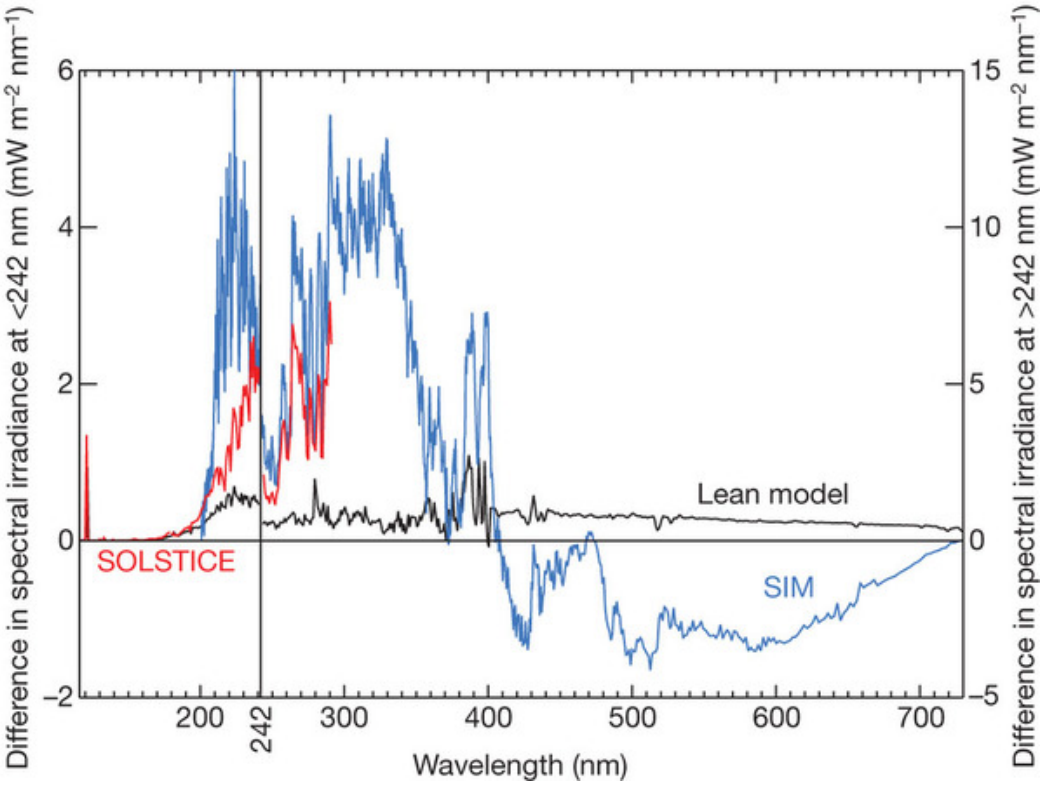


	1976	1986	1996	2007	2008	2009	2010
|B|(nT)	5.5	5.7	5.1	4.5	4.2	3.9	4.6

- strong decrease in the IMF during the recent minimum
- 2007 IMF already ~15% lower, and ~30% lower in 2009
- continuous decrease in 2008 – 2009 even if activity level at the Sun did not change much

(De Toma, 2011)

How well do we understand the relation between the way Sun works and its output?

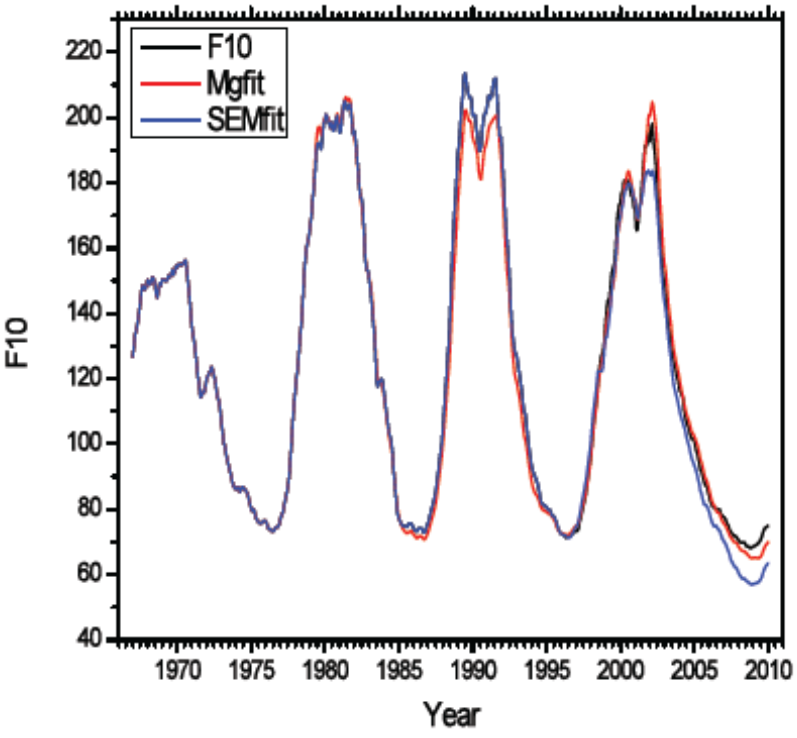


difference 2004-2008

(Haigh et al., Nature, 2010)

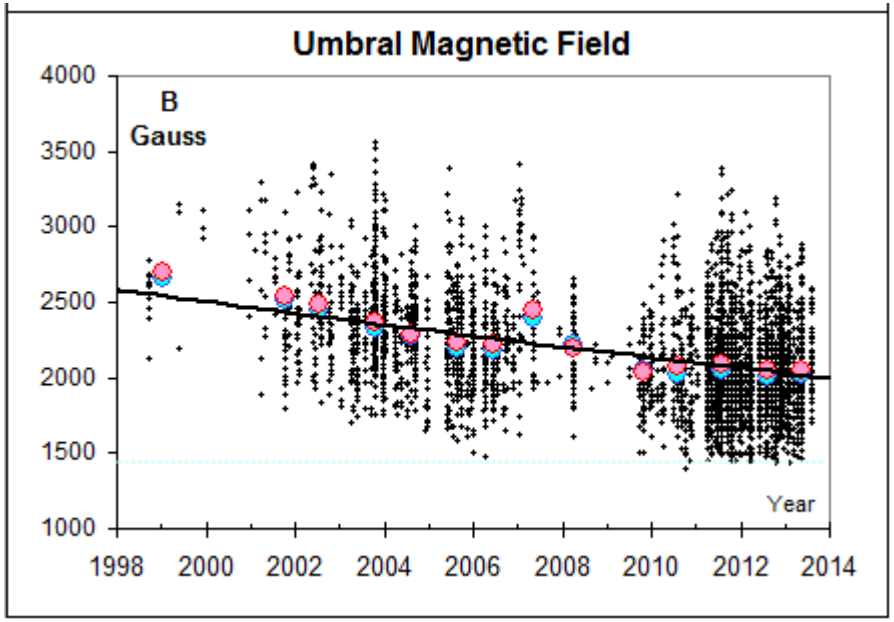
4-6 times larger observed decline in UV during the last sunspot min than predicted on the basis of our previous understanding;
increase in visible wavelengths where the model predicts decline

How reliable are the solar proxies we use?



Sunspot number is not a good proxy for the solar magnetic fields

(Penn and Livingston, 2011; Svalgaard, 2013)



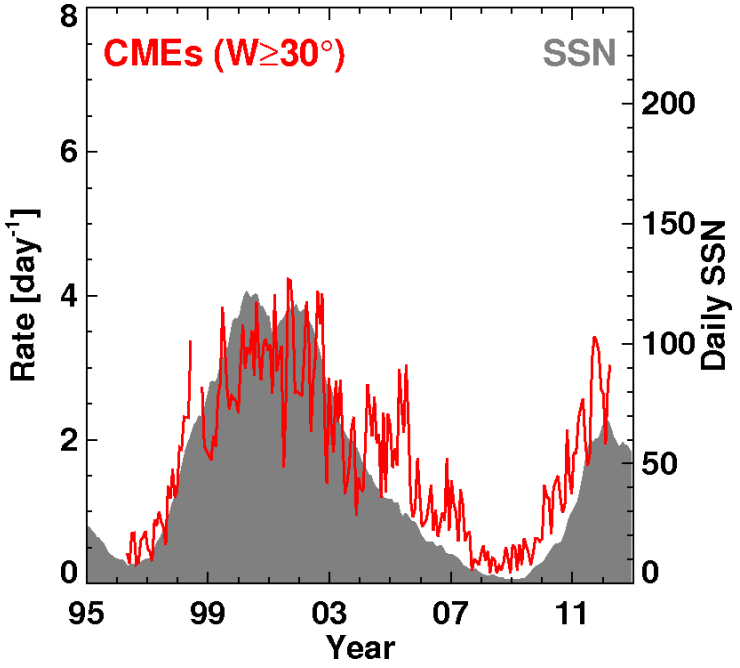
F10 is not a good proxy for solar EUV at very low values

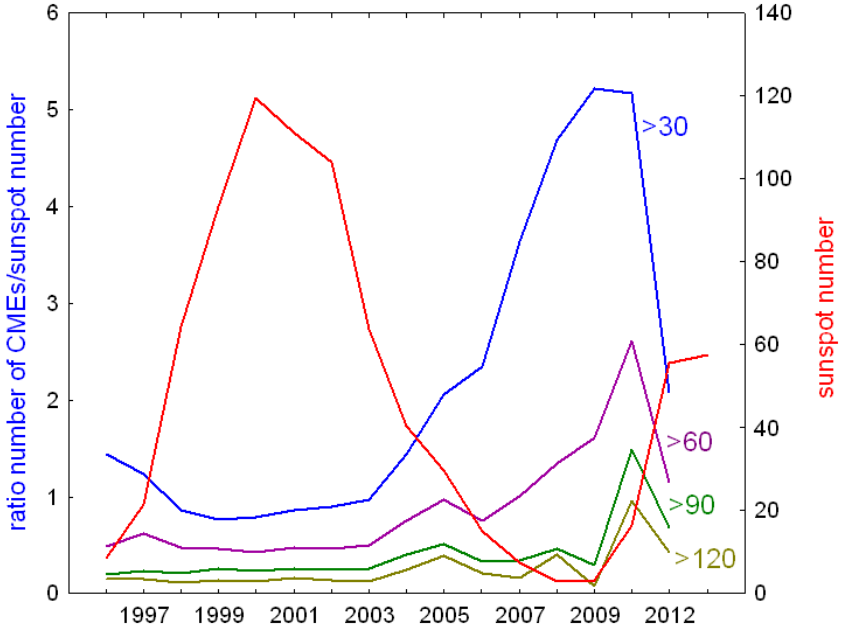
– **F10** down2.3% (Araujo-Pradere, 2011)

– **MgII** down 7%

– **SOHO SEM** down 14%

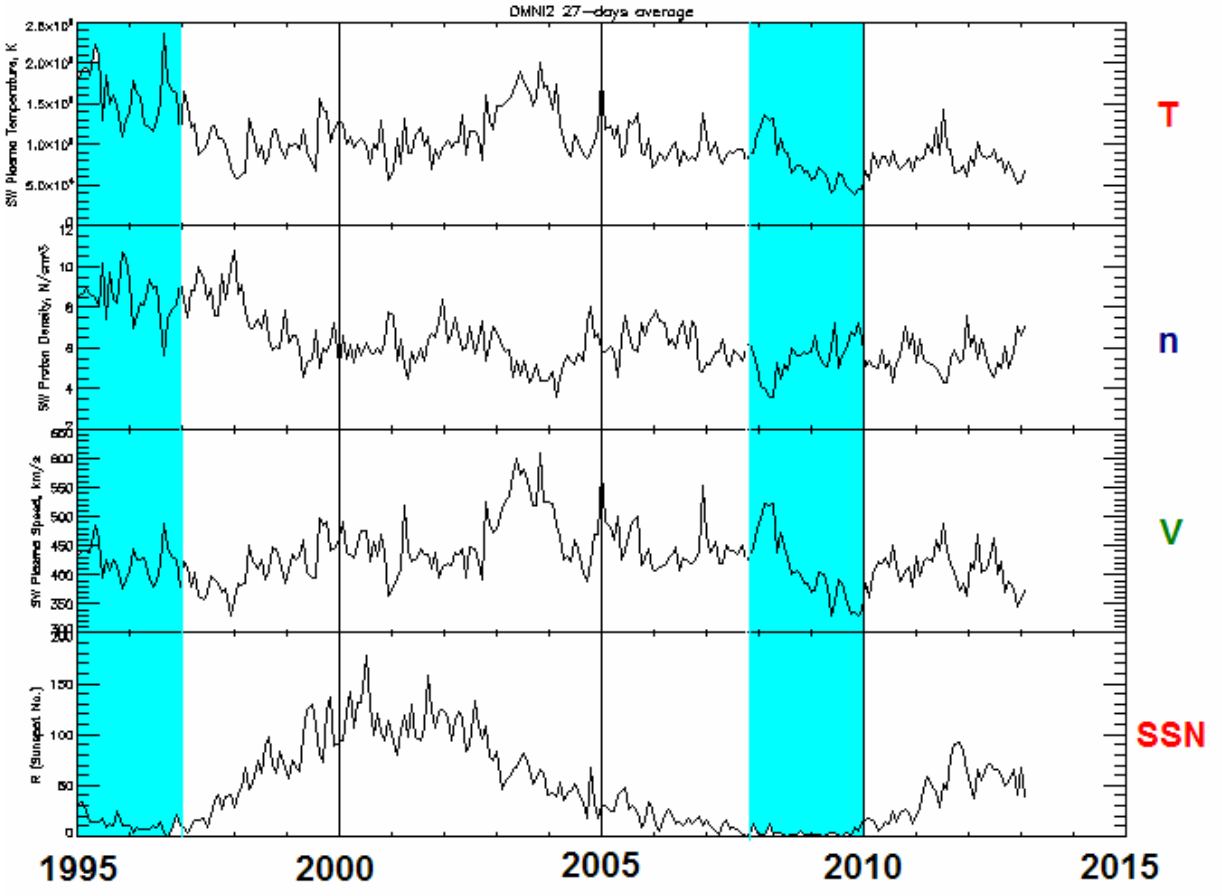
How well do we understand the relation between the way Sun works and its output?





Almost the same number of CMEs this sunspot minimum with a much lower number of sunspots

How well do we understand the relation between the way Sun works and its output?



OMNI

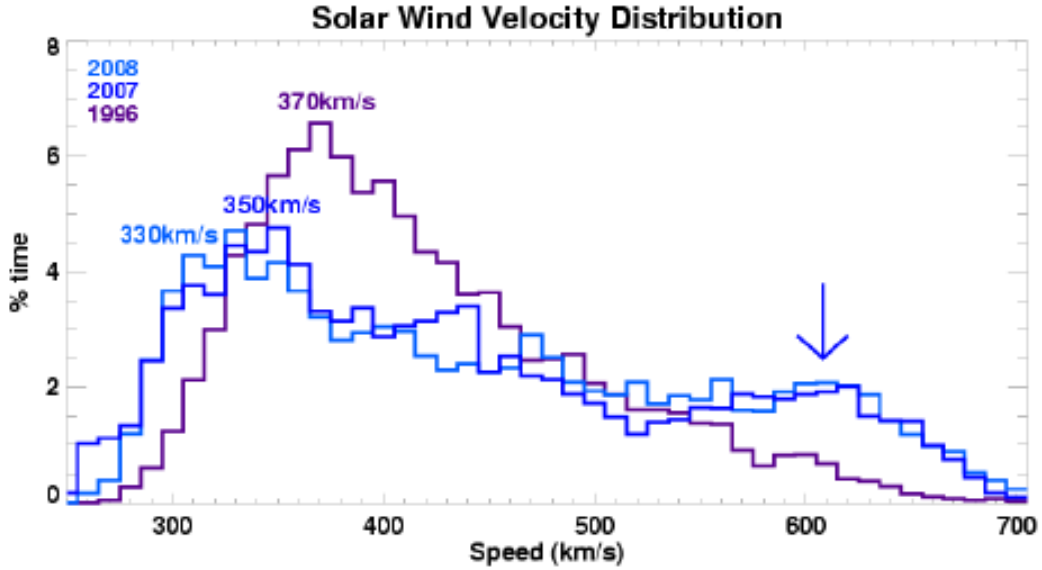
colder and less dense solar wind this sunspot minimum

How well do we understand the relation between the way Sun works and its output?

SOLAR WIND SPEED

- mean velocity about the same but very different velocity distribution

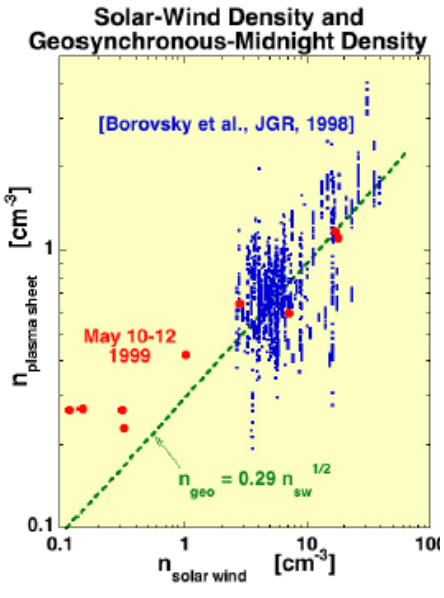
year	v (km/s)
1996	423
1986	453
2007	440
2008	450



- in 1996 the Earth was inside fast wind (> 500km/s) about 17% of the time compared to 29% and 33% in 2007 and 2008
- high velocity tail associated with high speed streams from low-latitude, long-lived coronal holes

(De Toma, 2011)

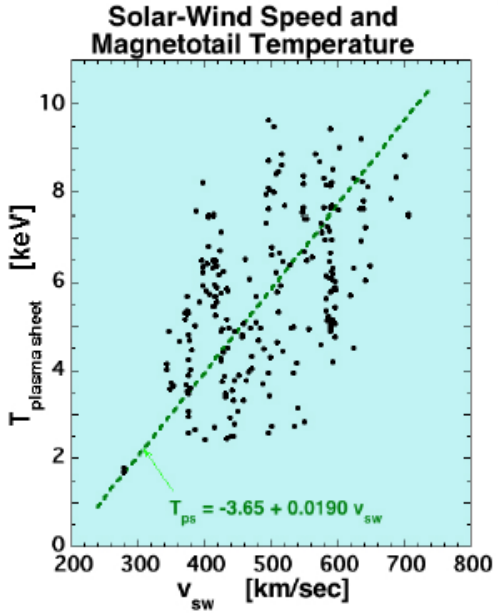
How well do we understand solar variability effects in the magnetosphere?



Low-Density Solar Wind Produces a Low-Density Plasma Sheet

Possible Impacts of low-density plasma sheet:

- Weaker magnetospheric plasma waves
- Weakened ring current
- Changes in field-aligned currents
- Changes in the aurora



Slow Solar Wind Produces a Cool Plasma Sheet

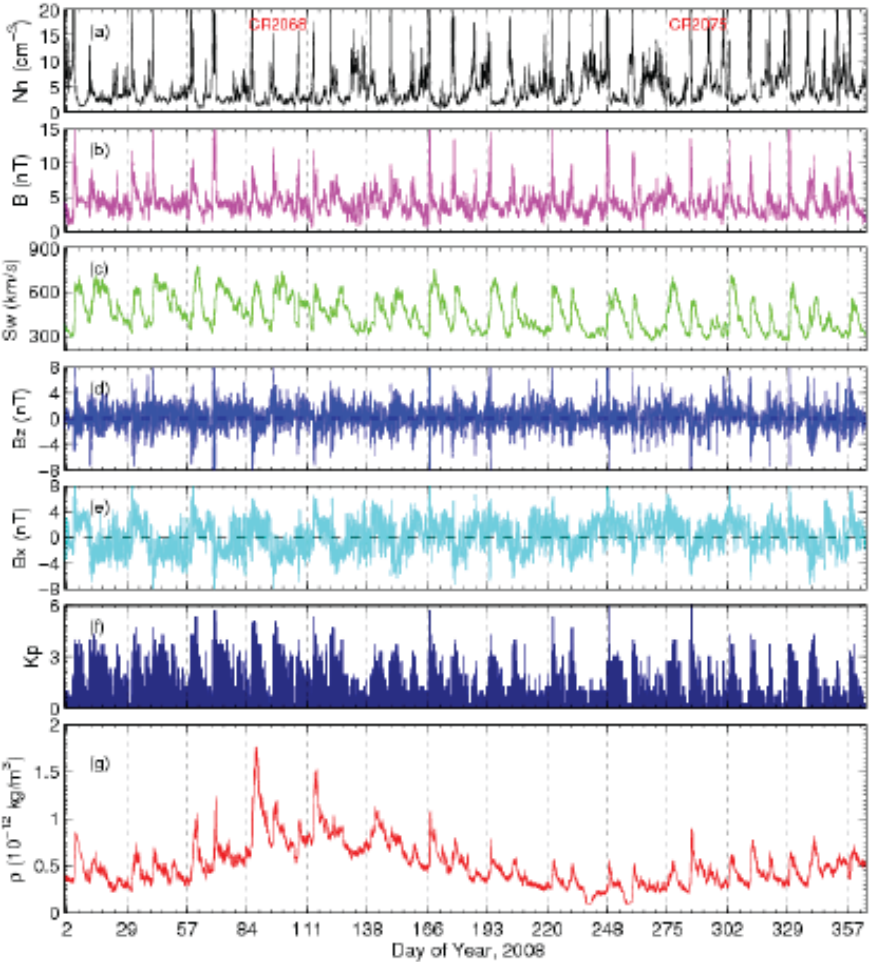
Impact of a cool plasma sheet:

- Better fuel for the ring current

Can the state of the Earth's magnetosphere be specified and predicted to high accuracy, based on inputs from the sun and solar wind?

How well do we understand solar variability effects in the upper atmosphere?

38 CIRS in 2008!!



Solar wind density

IMF |B|

Solar wind speed

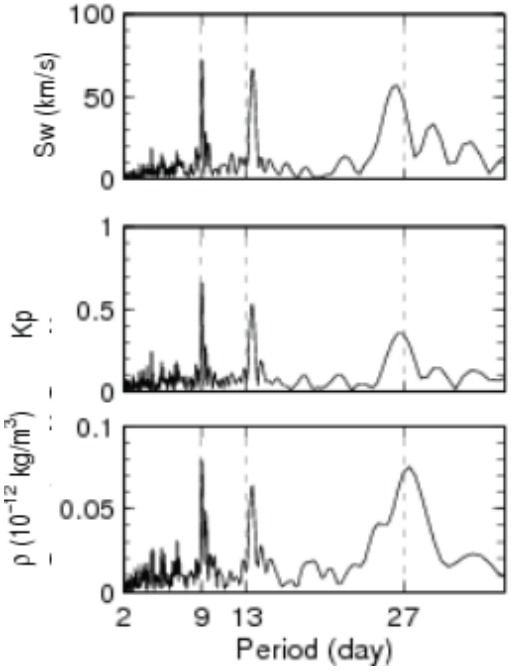
IMF Bz

IMF Bx

Geomagnetic Activity Index

Density - 400km altitude

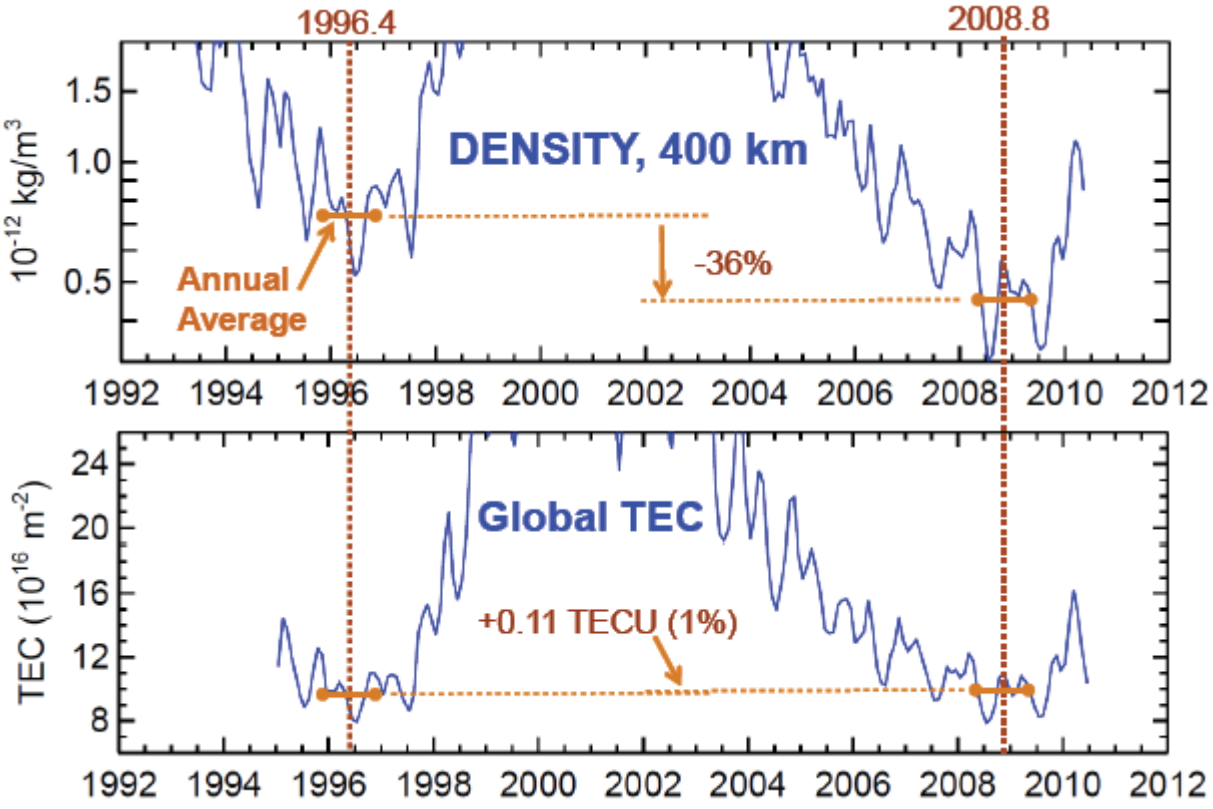
Lei et al., Solar Phy., 2010



Thayer, 2011

How well do we understand solar variability effects in the ionosphere?

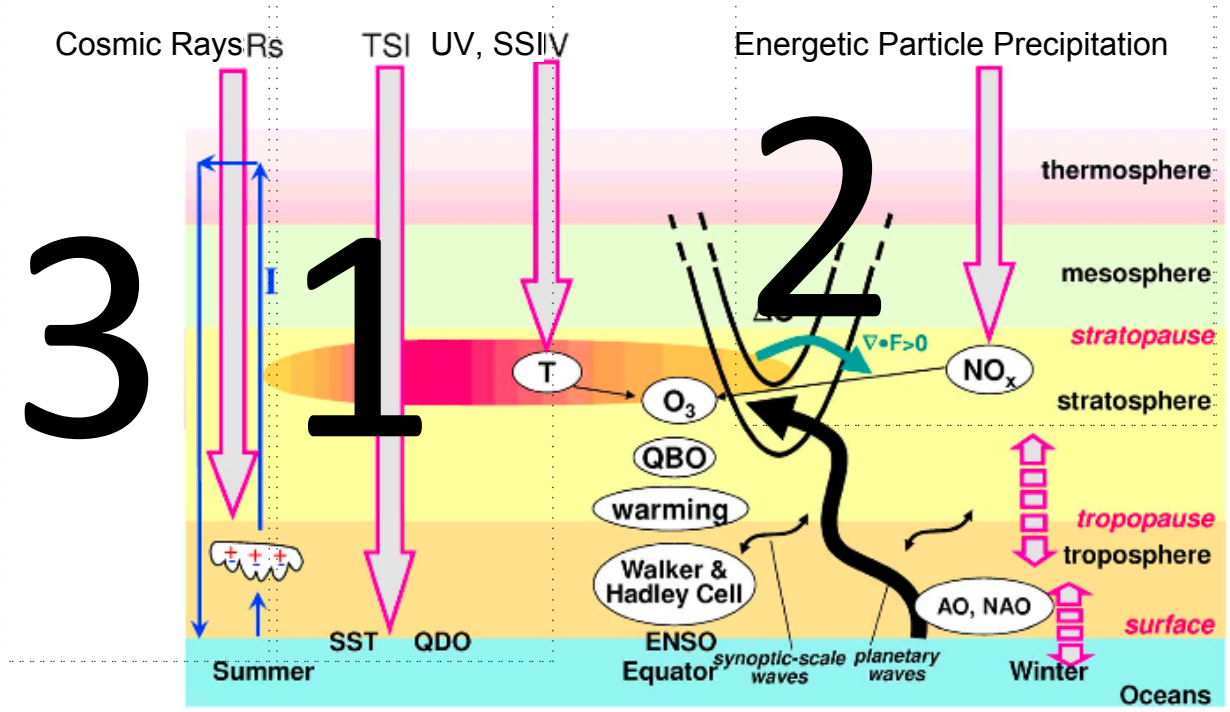
Density showed a 36% inter-minima decrease, whereas TEC showed very little change.



Emmert, 2011

Variance among a priori EUV indicators → large uncertainty in density change attribution.
TEC data suggest small inter minima EUV change

How well do we understand solar variability effects on the middle and lower atmosphere?



1. Total Solar Irradiance (TSI). Surface

   Solar Spectral Irradiance (SSI). Stratosphere
2. Energetic Particle Precipitation. Stratosphere-mesosphere-lower thermosphere
3. Cosmic Rays. Lower stratosphere-troposphere

upward energy flow in the form of waves

Figure 21. Schematic diagram of solar influence on climate based on *Kodera and Kuroda* [2002]. Shown are the direct and indirect effects through solar irradiance changes (TSI and UV) with respect to S_{max} as well as corpuscular radiation effects (energetic particles and GCRs). The two dashed arrows denote the coupling between the stratosphere and the troposphere and the coupling between the ocean and the atmosphere.

Solar versus anthropogenic Influence on Climate in the Context of Weak Solar Activity

In the light of the observed and expected change in Sun's behavior, the new program will attempt a better understanding of:

- **Solar activity, evolution and extrema**
- **Geoeffective solar events: occurrence, propagation, space weather effects**
- **Response of the magnetosphere to Sun/solar wind driving**
- **Role of the Sun and middle atmosphere/ thermosphere/ionosphere in climate**

Four Elements of VarSITI

- Solar Evolution and Extrema (SEE)
- International Study of Earth-Affecting Solar Transients MiniMax24/ISEST
- Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN)
- Role Of the Sun and the Middle atmosphere/ thermosphere/ionosphere In Climate (ROSMIC)

Solar Evolution and Extrema (SEE)

- Reproduce long-term solar activity based on observations, proxies, and dynamo models
- Are we at the verge of a new grand minimum? If not, what is the expectation for cycle 25?
- For the next few decades, what can we expect in terms of extreme solar flares and storms? What is the largest solar eruption/flare possible?
- What is the expectation for periods with absence of activity?

Co-chairs: Petrus Martens, Vladimir Obridko, Dibyendu Nandi

International Study of Earth-Affecting Solar Transients ISEST/MiniMax24

- ISEST – initially a program within CAWSES-II Task Group 3 (How does short-term solar variability affect the geospace environment?)
- MiniMax24 – initially a year-long SCOSTEP campaign on Sun-Earth connections
- Merged into ISEST/MiniMax24 to:

➢ understand the propagation of solar transients through the space between the Sun and the Earth

➢ create a database of Earth-affecting solar transient events

➢ develop empirical, theoretical, and numerical models

➢ improve space weather prediction capabilities

Co-chairs: Jie Zhang, Manuela Temmer

Specification and Prediction of the Coupled Inner-Magnetospheric Environment (SPeCIMEN)

- How does the inner magnetosphere respond as a coupled system to Sun/solar-wind driving?
- combination of physical and statistical (machine learning) modeling, theory, and observations from various platforms
- quantitative prediction and specification of the Earth's inner magnetospheric environment based on Sun/solar wind driving inputs

Co-chairs: Jacob Bortnik, Craig Rodger

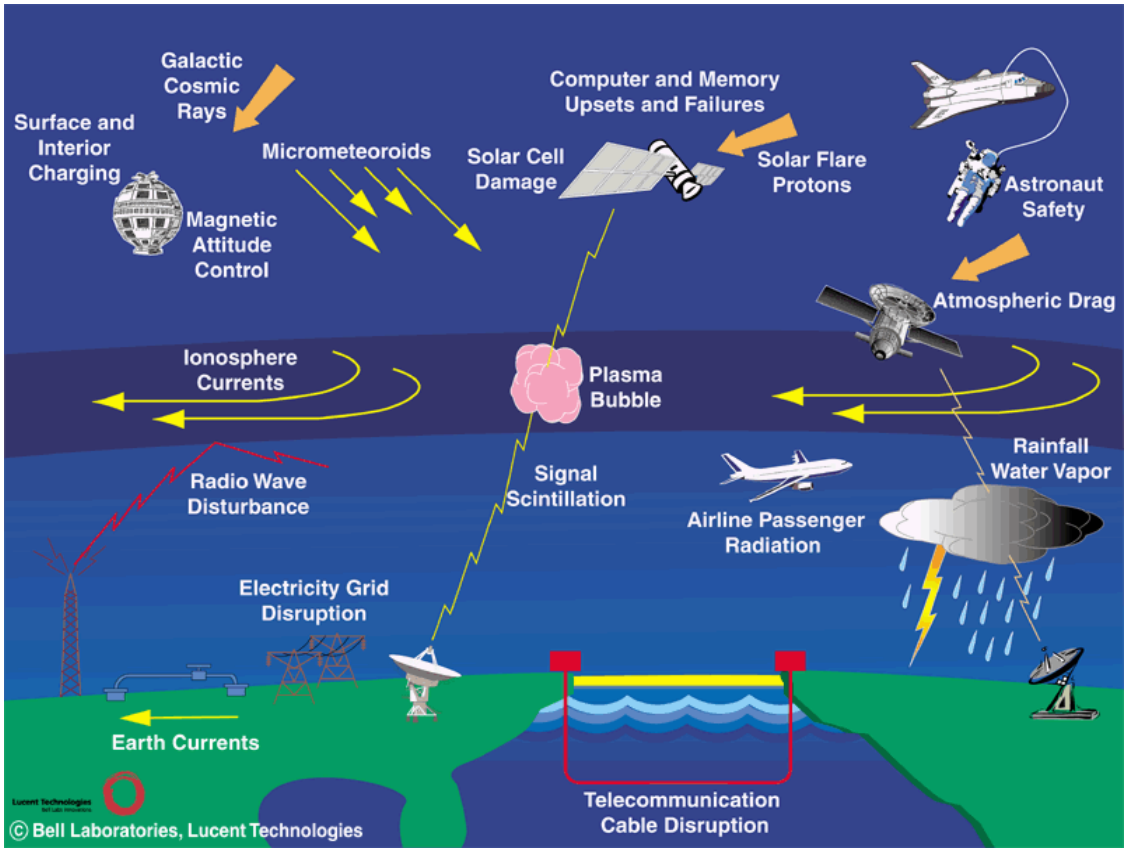
Role Of the Sun and the Middle atmosphere/ thermosphere/ionosphere In Climate (ROSMIC)

- impact of solar forcing on the entire atmosphere
- relative importance of solar irradiance versus energetic particles
- transfer of the solar signal from the thermosphere to the troposphere
- coupling within the terrestrial atmosphere
- reconstructions and predictions of TSI and SSI

➢ Better understanding of the impact of solar activity on the entire atmosphere, relative to anthrogenic forcing and natural long term variability

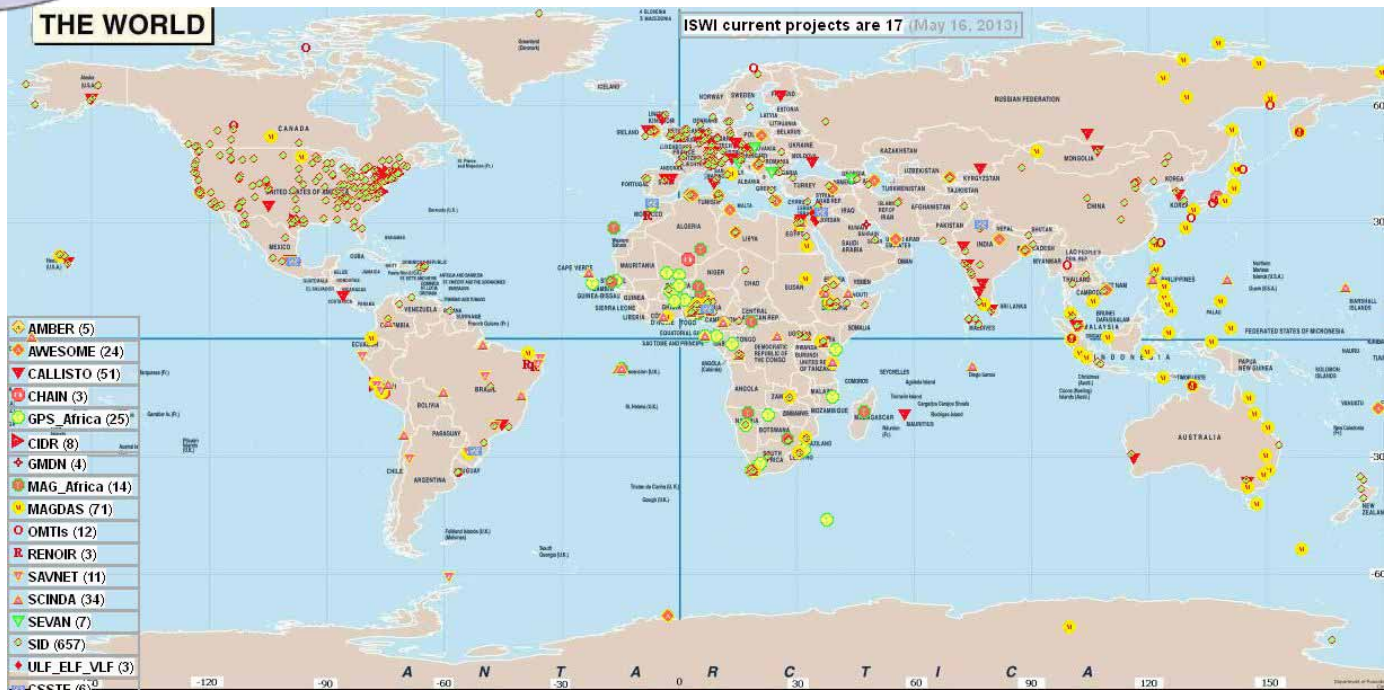
Co-chairs: Franz-Josef Lübken, William Ward

All VarSITI elements are relevant to the broad concept of “space weather”



“Space weather is the physical and phenomenological state of natural space environments. The associated discipline aims, through observation, monitoring, analysis and modelling, at understanding and predicting the state of the Sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them; and also at forecasting and nowcasting the possible impacts on biological and technological systems.”

ISWI and VarSITI: much in common



ISWI is a program of international cooperation to advance the **space weather** science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public and students.

SCOSTEP runs international interdisciplinary scientific programs and promotes **solar-terrestrial physics** research by providing the necessary scientific framework for international collaboration and dissemination of the derived scientific knowledge

COPUOUS and SCOSTEP

- COPUOS reviews the scope of international cooperation in peaceful uses of outer space, devises programs in this field and encourages continued research and the dissemination of encourages continued research and the dissemination of information.
- SCOSTEP promotes/provides the necessary scientific framework for international collaboration and dissemination of the derived scientific knowledge.
- SCOSTEP organizes/cosponsors Space Science Schools (e.g. IHY, ISWI) ISWI) - an important capacity building activity; future schools in South Africa, and South America.
- SCOSTEP has high relevance and synergy to all COPUOS activities as applied to Sun - Earth connections.
- SCOSTEP will strive to contribute to the Permanent Space Weather Agenda of the Science and Technology Subcommittee of UNCOPUOS